UNITED STATES MARINE CORPS
Utilities Instruction Company
Marine Corps Engineer School
PSC Box 20069
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STUDENT HANDOUT
DESIGN INTERIOR ELECTRICAL WIRING SYSTEMS

3. LEARNING OBJECTIVES:

a. TERMINAL LEARNING OBJECTIVE:

Provided a building requiring an interior electrical wiring system, the construction plans for the building, a report detailing interior electrical system requirements, and references, design an interior electrical wiring system such that the wiring meets the requirements of the report and the National Electrical Code and the safety requirements of the references. (1141.08.05)

b. ENABLING LEARNING OBJECTIVES:

(1) Provided a list of standard construction symbols and a list of standard items found in a floor plan, without the aid of reference, match each item to it's symbol in accordance with TM 5-704. (1141.08.05a)

(2) Provided a list of standard electrical components and a list of standard electrical symbols, without the aid of reference, match each component to its symbol in accordance Wiring Skills, Unit 1 and TM 5-424. (1141.08.05b)

(3) Provided a list of definitions of standard electrical terms and a list of standard electrical terms, without the aid of reference, match each term to its definition in accordance with Wiring Skills, Unit 1 and TM 5-424. (1141.08.05c)

(4) Provided a list of electrical components, without the aid of reference, identify the operation of each component in accordance with Wiring Skills, Unit 1. (1141.08.05d)

(5) Provided the National Electrical Code and a list of electrical situations, with the aid of reference, identify one article that applies to each electrical situation in accordance with the National Electrical Code. (1141.08.05e)

(6) Provided a list of electrical equipment to be installed in each room and construction prints, with the aid of reference, calculate the general lighting load in accordance with the National Electrical Code. (1141.08.05f)

(7) Provided a list of electrical equipment to be installed in each room and construction prints, with the aid of reference, calculate the minimum number of branch circuits required in accordance with the National Electrical Code. (1141.08.05g)

(8) Provided a list of electrical equipment to be installed in each room and construction prints, with the aid of reference, calculate the total demand of the structure in accordance with the National Electrical Code. (1141.08.05h)

(9) Provided a list of electrical equipment to be installed in each room and construction prints, with the aid of reference, calculate the minimum size of the service entrance conductor in accordance with the National Electrical Code. (1141.08.05i)

(10) Provided a list of electrical equipment to be installed in each room and construction prints, with the aid of reference, calculate the minimum size of the neutral conductor in accordance with the National Electrical Code. (1141.08.05j)

(11) Provided a list of electrical equipment to be installed in each room and construction prints, with the aid of reference, calculate the over-current protection devices required in accordance with the National Electrical Code. (1141.08.05k)

(12) Provided a list of electrical equipment to be installed in each room and construction prints, with the aid of reference, calculate the size of the grounding electrode conductor in accordance with the National Electrical Code. (1141.08.05l)

(13) Provided a list of electrical equipment to be installed in each room and construction prints, with the aid of reference, select the proper size conductors for each branch circuit in accordance with the National Electrical Code. (1141.08.05m)

(14) Provided a list of electrical equipment to be installed in each room and construction prints, with the aid of reference, select the proper size boxes for each branch circuit in accordance with the National Electrical Code. (1141.08.05n)

(15) Provided a list of electrical equipment to be installed in each room, construction prints, and designated circuits, with the aid of reference, calculate the conduit to be installed in each designated circuit in accordance with the National Electrical Code. (1141.08.05o)

(16) Provided a branch circuit schedule, with the aid of reference, complete the branch circuit schedule in accordance with Wiring Skills Unit 1. (1141.08.05p)

(17) Provided a branch circuit material schedule, with the aid of reference, complete the branch circuit material schedule in accordance with Wiring Skills Unit 1. (1141.08.05q)

(18) Provided a service material schedule, with the aid of reference, complete the service material schedule in accordance with Wiring Skills Unit 1. (1141.08.05r)

(19) Provided a lighting fixture schedule, with the aid of reference, complete the lighting fixture schedule in accordance with Wiring Skills Unit 1. (1141.08.05s)

BODY

1. Basic Construction Symbols:

a. Understanding construction symbols is important when determining the best placement of components to serve the user of the electrical system. Foreseeing the needs of an electrical system allows the planner to meet the necessary requirements as they apply. Placement of a switch on the proper side of a doorway or measuring a wall to ensure enough electrical outlets are provided, are just some of the many examples of using and interpreting construction symbols commonly found on a floor plan.

b. Floor plans are a cross-sectional view of a building. The horizontal cut crosses all openings, regardless of their height from the floor. Note that a floor plan shows the outside shape of the building; the arrangement, size, and shape of the rooms; the type of materials; and length, thickness, and character of the building walls. A floor plan also includes the type, width, and location of the doors and windows; the types and locations of utility installations; and the location of stairways.

c. The most common type of door is the single hinge door. This can be an interior or exterior door. The direction of the swing denotes the operation of the door. This will be important when selecting the location of switches.

d. Three lines drawn parallel with the sides flanked by one to two lines represent double hung windows.

e. Folding doors are represented by two "V" shaped characters drawn one to each side of a doorway. The point of the "V" shaped character represents the part of the door section, which is hinged. The first hinged point of both door sections is found where the character makes contact with the mouth of the doorway.

f. Sliding doors are represented by two sets of parallel lines. One end of each set is drawn meeting the flanks of the doorway. The parallel lines representing each of the two sliding doors overlap approximately midway of one another.

g. A wall is represented by two lines drawn parallel. The distance between the two lines relates to the thickness of the wall. Some walls may also be colored in with a pattern to denote the material the wall is constructed of.

h. Steps are represented by two parallel lines, with evenly spaced lines drawn between them. Sometimes an arrow will denote the direction of the stairs and the number of risers may also be given.

i. Swinging doors are represented by two half circles drawn opposite from each other with a line in the center.

2. <u>Electrical Symbols</u>:

a. The various electrical symbols found in most books and technical manuals may vary slightly, but usually the resemblance can be identified using the following set of symbols. Always make sure to check all legends that come with the plans or ask the designer for any symbols that you are not familiar with.

(1) Ceiling outlet

(2) Wall mounted outlet

(3) Lamp holder with pull switch

(4) Floor outlet

(5) Fan outlet

(6) Crossed wires that are connected or spliced

(7) Crossed wires that are not connected

(8) Range outlet

(9) Dryer outlet

(10) Special purpose 240V outlet

(11) Duplex outlet

(12) Grounding type duplex outlet

(13) Split circuit outlet (split-wired receptacle)

(14) Weather proof outlet

(15) Ground fault circuit interrupt outlet (GFCI)

(16) Battery

(17) Switch and fuse

(18) Fuse

(19) Fluorescent fixture

(20) Single pole switch (snap switch)

(21) Door switch

(22) Double pole switch

(23) Three-way switch

(24) Four-way switch

(25) Switch with pilot

(26) Pushbutton

(27) Buzzer

(28) Bell

(29) Chime

(30) Clock

(31) Motor

(32) Junction box

(33) Annunciator

(34) Circuit breaker

(35) Ground connection

(36) Panelboard

(37) Circuit number

(38) Home Run

(39) Double Home Run

(40) Number of conductors in a raceway

(41) Branch circuit wiring

3. Standard Electrical Terms:

a. **Alternating current**- An electric current that reverses its direction at regular intervals.

b. **Ampere**- The unit of measure of electric current which will flow through one ohm under a pressure of one volt.

c. **Branch circuit**- That portion of the wiring system between the final over current device protecting the circuit and outlets.

d. **Buzzer**- A doorbell with the hammer and gong removed.

e. **Cable**- Two or more wires grouped together in a single jacket; also a stranded wire heavier than No. 4/0.

f. **Carrying capacity**- Amount of current a wire can carry without overheating.

g. **Circuit**- Any combination of wires and devices that permit an electric current to flow from the source to a load and back to the source. Three parts of a circuit are (1) source (2) conducting path (3) load. A switch is also a part of a circuit but is optional.

h. **Circuit Breaker**- A switching device which will open a current carrying circuit under abnormal (high) current conditions without injury to itself. Note that the circuit breaker is placed in the hot side of the circuit.

i. **Conduit**- A type of tubing, which is used to enclose and protect electrical wiring. There are many different types and sizes depending on the application needed.

j. **Rigid conduit**- Made to the same dimensions as standard pipe, usually made of steel, threaded on both ends, and comes in ten foot lengths.

k. **Thin wall conduit (Electrical Metallic Tubing**)- Galvanized, light in weight, comes in ten foot lengths with no couplings.

l. **Flexible conduit (Sometimes referred to as Greenfield)**- Is similar to B-X(trade name), but it doesn't contain wires pre-installed by the manufacturer, and comes in coils. It is used when it is necessary to make difficult bends.

m. **Conductor**- Wire or cable that is capable of carrying electric current.

n. **Connector**- A device used to connect or join one circuit or terminal to another. Also a device used in raceways to connect conduit or cable to boxes and conduit bodies.

o. **Cycle**- is one complete reversal of an alternating current from positive to negative and back to starting point (360 degrees).

p. **Efficiency**- The ratio between the output power and the input power. Efficiency ratings are commonly given to transformers, generators, and electric motors.

q. **Electric potential** - is the pressure or voltage of electricity.

r. **Electric service**- The conductors and equipment for delivering energy from the electricity supply system to the wiring system of the premises served.

s. **Electrical codes**- Various rules and regulations for the operation and installation of electrical devices.

t. **Fault**- Short circuit between two hot wires or one hot wire and the neutral or between a hot wire and ground.

u. **Fish wire (fish tape)**- Tapes made of tempered spring steel used to pull wires through conduits and wall openings.

v. **Frequency**- Number of cycles per second expressed in hertz (60 Hz).

w. **Ground**- A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and earth, or to some conducting body which serves in place of earth.

x. **Line drop**- Voltage loss in conductors in a circuit due to their resistance. Commonly referred to as voltage drop.

y. **Load**- The resistance connected across a circuit which determines current flow and energy used.

z. **Neutral conductor**- The neutral (grounded) conductor of a three wire system which carries the unbalanced current; that is, the difference between the current in the two hot conductors.

aa. **Ohm**- The unit of measure of resistance through which one volt will force one ampere.

ab. **Open circuit**- When a circuit is broken or a load is removed; not a complete path for current to flow.

ac. **Outlet**- The point or points where electric power is taken from conductors and consumed.

ad. **Overload**- A greater load applied to a circuit or device than the circuit was designed to carry.

ae. **Parallel circuit**- A circuit, which contains two or more paths for electricity, supplied by a common voltage source.

af. **Series circuit**- A circuit in which the same current flows through all the devices (one path).

ag. **Service switch**- The main switch or breaker that connects all of the circuits in a building to the service wires.

ah. **Service entrance wires**- The wires from the point where the power supplier's wire stops, up to the service equipment. Commonly referred to as service entrance conductors.

ai. **Short circuit**- A direct connection across the source, which provides a zero resistance path for the current.

aj. **Transformer**- A device which transfers energy from one circuit to another by electromagnetic induction. Rated in KVA’S.

ak. **Volt**- The unit of measure of the pressure required to force one ampere through a resistance of one ohm.

al. **Voltmeter**- An instrument for measuring electric pressure or voltage in a circuit.

am. **Ohmmeter**- An instrument for measuring resistance in a circuit or a device.

an. **Ammeter**- An instrument for measuring current flow in a circuit, (clamp on).

ao. **Watt**- A unit of measure of the total energy flowing in a circuit at any given moment. A measurement of electric power. Many electrical loads are rated in watts, which tells how much power that item consumes.

ap. **Watt-hour meter**- A meter that indicates the instantaneous rate of power consumed by a device or circuit.

4. Electrical Components:

a. Ground Fault Circuit Interrupter (GFCI):

(1) GFCI's come in two forms.

(a) Ground fault breaker

(b) Ground fault receptacle

(2) Both operate on the same principle. A magnetic sensor monitors the current flow in the hot and neutral wires supplying power to a load or circuit. When a fault occurs, the current flow in the neutral wire is less than current flow in the hot wire. This condition of unequal current causes voltage to be induced in the monitor pick up coil. The amplifier has a small voltage input and the amplifier output trips the breaker.

(3) The unit will open the circuit within 1/30th of a second after the sensor detects a leakage as small as five milli-amperes. Ground fault protection will only provide ground fault protection.

(4) GFCI’s will not protect against short circuits or overloads.

b. <u>Three Way Switch</u>:

(1) The three-way switch is used in pairs to control a load from more than one location. The three-way switch is a single pole, double throw switch (SPDT). The three-way switch has three terminals. One terminal is called the common point or hinged point. Internally this terminal makes contact with one of the remaining two terminals. The remaining two terminals are called traveler terminals. Traveler terminals are connected to another set of traveler terminals on another three-way switch. The common terminal “c” can usually be identified as the terminal that is colored or darker than the traveler terminals, or the terminals may be marked on the housing of the switch with “c” and “t”. If the terminals are not marked a continuity check can be done using an ohmmeter to determine which terminal is the common.

(2) When two three-way switches are connected together, one switch is fed current while the other switch is connected to the load. Current is fed and received by the load through the common terminals.

c. <u>Four Way Switch</u>:

(1) The four-way switch has four terminals. It is only used in conjunction with two three-way switches. It is used to control a load from three or more locations. The four-way switch is similar to a double pole, double throw switch (DPDT).

(2) The four-way switch reverses the connections from one pair of wires to another. These wires are known as travelers. When installing a four-way switch it is important to ensure that the terminals match the travelers on the three way switches at each end. The four-way switch comes in two types:

(a) Through wired - Travelers from a 3-way, or another 4-way switch, would connect to the top and travelers to the other 3-way to the bottom. When the handle is actuated, electrical connections inside the switch change from straight across to diagonally across, or vice versa.

(b) Crossed wired - In the crossed type, bottom, one of the travelers coming in from the left goes to a switch terminal on that side. The other one crosses over to the terminal on the right. Also, on the outgoing travelers one connects on the right side, while the other crosses over to the left. Operation of the switch handle changes inside connections from straight across to up-and-down, or vice versa. If the type of switch is unknown a continuity check can be done using a ohmmeter to determine the type of 4-way switch.

d. <u>Split Wired Receptacle</u>:

(1) The purpose of a split-wired, duplex receptacle is to allow each receptacle to be controlled by a switch or be fed by a separate circuit.

(2) It also allows one side to remain hot while the other can be switched on or off. This is done by taking a duplex receptacle and breaking the brass tab on the hot leg side of the outlet. This disconnects the top from the bottom and allows conductors from the hot side of two separate sources to be connected. On the other side of the duplex outlet, the brass tab remains connected. This will allow the neutral to be shared. For this reason it is best to feed the top and bottom from opposite sides of 240-volt line. This helps to prevent overloading the neutral.

e. Door Buzzer:

(1) A door buzzer is a signaling device used for home or business. It is another component, which is used in today's interior wiring systems for convenience. The door buzzer can be used by the military in classified or controlled areas and can serve in the field as a warning system in field type armories to alert reaction force teams.

(2) The door buzzer operates off low voltage. A transformer reduces the voltage to a safe working voltage (8-24V). When the button is pushed, it closes the circuit from the transformer to the buzzer and produces a buzz or chime.

f. Thermostat:

(1) Thermostats are used to turn cooling and heating appliances on and off. This switch operates by reacting to the surrounding (ambient) temperature. The majority of thermostats operate off low voltage (24V) however, there are some thermostats that operate off line voltage, mainly on the commercial side. When installing a thermostat, make sure to read the instructions so that the right voltage and conductors are used. There are two common thermostats.

(2) One type of thermostat consists of two different types of metal welded together. This is called a bimetallic strip. It works by each type of metal reacting at different rates to heat and or cold. As two metals expand or contract in response to the temperature, the bimetallic strip will bend causing the breaking or completion of the circuit. The bimetallic strip is commonly wrapped in the shape of a coil. The most common problem with the bimetallic strip is arcing. The strip never moves very far or very fast. This means that the contacts open and close very slowly. This can lead to excessive amounts of arcing on the contacts, which can lead to deterioration of the contacts and faulty operation. For this reason bimetallic strips are being used less and less for switching contacts in thermostats.

(3) The mercury switch is another type of thermostat. Mercury moves back and forth inside a glass tube attached to a thermostatic spring. The spring reacts to the environmental temperature. This spring is actually a bimetallic strip coiled. Change in temperature causes the mercury to move from one end of the tube to the other, closing or opening the circuit, depending on the direction of movement. When installing the mercury switch thermostat it is important to ensure that it is mounted level in order for the calibrations to be correct.

g. Timer:

(1) Timers are components which turn loads off and on at preset times. They are used to turn on and off lights, water sprinklers, etc.

(2) The timer is simply a set of contacts that are activated by a clock motor to open and close a circuit. Care should be taken in the connection of the wires to the clock motor to ensure the neutral is not disconnected as the clock opens or closes contacts. The clock motor needs to have electrical power driving it at all times.

(3) There are many different types of timers for home and commercial use. Some timers work on a weekly clock and have a different set of contacts for each day of the week. When installing a timer it is always important to fully read the instructions.

h. Dimmer:

(1) The dimmer switch is a solid-state device designed to control the intensity of an incandescent light from full brightness to very dim by turning a knob. Dimmers are to be used only with certain maximum wattage loads. Home-type dimmers are normally rated at 600 watts. These components come in many other load ratings. When selecting a dimmer it is necessary to estimate the load, which the dimmer will control. Always count each light fixture as 100 watts for each lamp holder. When choosing a dimmer, select a dimmer with the next highest capacity.

(2) The second function is that of a switch. Dimmers are normally equipped with single-pole switches. There are dimmers equipped with three-way switches. Never use dimmers to control receptacles. This could result in damage to the load. Some dimmer switches have pilot lights to indicate the contacts are closed.

i. Photo Control:

(1) The photo control is used to control lights in areas that require constant illumination. Such as Armories, parking lots, streetlights, and standing lights around Barracks.

(a) The photo control responds to light. Light from the sun opens its contacts, opening the circuit it controls.

(b) It facilitates illumination during an overcast day whereas a timer wouldn't.

(2) When the ambient light level reaches a preset level, the photo control opens the circuit, turning off the light. Incidence of light upon the sensitive surface of the photo control creates a small current that opens a relay and turns off the load. When the incidence of light falls below the preset level, the relay closes and supplies the power to the load.

j. Fluorescent Lamp:

(1) The fluorescent lamp is becoming more and more popular in today's lighting circuits. Fluorescent lights are initially more expensive to install, but over a period of time are less expensive than incandescent lighting. In the past fluorescent lighting was limited to commercial uses, and kitchens and bathrooms in residential. Now they are even being used in applications as small as table lamps. The main benefits of fluorescent lighting are:

(a) It has higher efficiency. It produces two to three times as much light per watt power compared to the incandescent lamp. The average fluorescent bulb is rated between 30 and 40 watts, compared to 60 to 75 watts for the average incandescent bulb.

(b) It can light a large surface area and has better distribution of light with less glare and shadows. This provides less strain on the eyes.

(c) It produces less heat.

(2) Operation:

(a) The heaters act as cathodes and emit electrons when heated.

(b) When the heaters are hot enough a high voltage pulse travels across the tube between the heaters.

(c) The high voltage causes the argon gas to become electrically charged or ionized.

(d) The charged argon causes the mercury to become mercury vapor giving off ultraviolet light

(e) The ultraviolet light makes the phosphorus coating on the tube glow and produce light.

(3) Starters:

(a) Preheat starters require a separate starter

1 Thermal type

2 Glow type

3 Manual type

(b) Instant start

(c) Rapid starts, most new ballast's are this type.

5. National Electrical Code:

a. The National Electrical Code is a guidebook. As it stands by itself, is not a law. Local and state governments may adopt the National Electric Code into laws regarding building codes. If this happens then the NEC becomes a law as a part of the building codes. The NEC even tells us it is not a law. On page 70-i it states "This Code is purely advisory as far as the NFPA (National Fire Protection Agency) and ANSI (American National Standards Institute) are concerned, but is offered for use in law and for regulatory purposes in the interest of life and property protection.

b. The NEC is divided into nine major chapters containing articles and tables. When I speak of an article and table, I refer to the article or table number and not the page number. This is an important step in learning how to use the Code. For instance, article 240-6 gives the standard ampere ratings, not page 70-72. The reason for this is that every time the NEC is reviewed and/or revised the articles and tables remain the same except for the revision.

c. Article 90 is not classified as a chapter. It is an introduction to the NEC. This article states the purpose, scope, and code arrangement, enforcement, formal interpretations, and examination of equipment for safety, wiring planning and metric units of measure. These articles all have a bearing on the rest of the NEC

(1) Article 90-1, Purpose as, stated in 90-1a, is the practical safeguarding of persons and property from hazards arising from the use of electricity.

(2) Article 90-2, Scope, says that the Code covers installations of electric conductors in public and private structures to include mobile homes, recreational vehicles, floating houses, yards, carnivals, parking lots, and industrial substations. The Code also covers optical fiber cable. The scope also tells what is not covered. This list includes ships, watercraft, railroad power systems such as electric trains (not the toys), communication equipment controlled by the communication utilities (telephones), automobiles, and installations under the exclusive control of electrical utilities (power companies).

(3) Article 90-3 covers code arrangement. Chapters 1,2,3, and 4 apply generally to all installations. Chapter 5,6, and 7 apply

to special conditions and these chapters modify or supplement chapters 1 through 4. Chapter 8 covers communication systems and chapter 9 consists of tables and examples. You will be using chapters 1,2,3,4, and 9 frequently.

(4) Article 90-4 covers code Enforcement. Once again the Code is not law unless adopted by local governments. This article also states that the authority having jurisdiction may modify the Code for its own use; however, effective **safety** must be maintained.

(5) Article 90-5 covers Mandatory rules, permissive rules, and explanatory material.

(a) Mandatory Rules. Mandatory rules of the code are those that identify actions that are specifically required or prohibited and are characterized by the use of the terms ***shall*** or ***shall not***.

(b) Permissive Rules. Permissive rules of the code are those that identify actions that are allowed but not required, are normally used to describe options or alternative methods, and are characterized by the use of the terms ***shall be permitted*** or ***shall not be required***.

(c) Explanatory Material. Explanatory material such as references to other standards, references to related sections of the code, or information related to a code rule, is included in the code in the form of fine print notes (**FPN**). Pine print notes are informational only and are not enforceable as requirements of the code.

(6) Article 90-6 covers Formal interpretations. These can be found in the "NFPA Regulations Governing Committee Projects"; however the authority having jurisdiction does not have to accept these findings.

(7) Article 90-7 covers Examination of Equipment for Safety. This article states that electrical equipment be "listed". An example of listed equipment is that which has undergone testing and carries the UL (Underwriters Laboratory) label. There are other agencies that also do testing.

(8) Article 90-8 covers wiring planning. This article says, have some common courtesy for the next guy. Leave ample space for future expansion.

(9) Article 90-9 covers Metric units of measure. The Code uses the US conventional units (inches, feet) of measurement and provides footnotes for conversion to the metric system known as International system of Units (SI).

d. CHAPTER 1: ART. 100-Chapter 1. General this chapter contains 34 Articles. We do not have the time to go in depth on each article. What I will do is give you an overview of the chapter.

(1) Article 100, Definitions. The list of definitions is one of the most important articles in the NEC. These definitions are used in practically every article in the Code. It is not important that you know the definitions by heart, but that you can find them when the need arises.

(2) Article 110 covers Requirements for Electrical Installation. Several articles here are worth mentioning.

(a) Article 110-3 (b) covers installation and use.

(b) Article 110-5 covers conductors. Conductors shall be copper, unless otherwise provided in the code.

(c) Article 110-12 covers Mechanical Execution of Work. Electrical equipment shall be installed in a neat and workmanlike manner. This article is similar to article 134 of the UCMJ, in that it's a "catch all" article.

(d) Article 110-14(a) covers electrical connections. Terminals for more than one conductor and terminals used to connect aluminum shall be so identified.

(e) Article 110-26 covers spaces about electrical equipment.

1 Table 110-26(a)

(f) Article 110-27 covers guarding of live parts.

e. Chapter 2 covers Wiring Design and Protection this chapter is divided up into articles and tables. Chapter 2 will be the primary reference for planning the interior electrical system. This chapter is easier to understand if you look at the general divisions.

(1) Article 200 covers use and identification of **grounded,** (neutral) conductors.

(a) Article 200-2 covers grounded conductors in premises wiring systems.

(b) Article 200-6 covers Identification of grounded conductors.

(c) Article 200-10 Identification of terminals.

(2) Article 210 covers branch circuits. This is an important section of the codebook. We will be referencing this article throughout the rest of this lesson.

(a) Article 210-2 covers other articles for specific-purpose branch circuits.

(b) Article 210-4 covers multiwire branch circuits.

1 Dwelling units

2 Identification of ungrounded conductors

(c) Article 210-7 covers receptacles and cord connectors.

1 Grounding type

2 Replacements

3 Non interchangeable types

(d) Article 210-8 covers ground fault protection for personnel.

1 Dwelling units

2 Other than dwelling units

(e) Article 210-11 covers branch circuits required.

(f) Article 210-52 covers placement of dwelling unit receptacle outlets.

(g) Article 210-70 covers lighting outlets required.

(3) Article 215 covers the installation requirements and minimum size and ampacity of conductors for feeders supplying branch circuit loads as computed in accordance with article 220.

(4) Article 220 covers branch circuit, feeder, and service calculations. Article 220 provides requirements for determining the number of branch circuits required and for computing branch circuit, feeder, and service loads. This will be the most used article during this class.

(5) Article 225 covers outside branch circuits and feeders. Article 225 covers electric equipment and wiring located outside of public and private buildings.

(a) Article 225-18 covers clearances from ground.

(6) Article 230 covers services, service conductors, and equipment. It also covers the number, type, size, and installation requirements.

(7) Article 240 covers over current protection. It provides the general requirements for over current protection and over current protection devices for both 600V and below and 600V and above. Article 240-6 covers standard ampere ratings.

(8) Article 250 covers grounding. Grounding is probably the most important and misunderstood section in the code. When installing an electrical distribution system it is imperative to properly ground and bond the system. Most electrical accidents are the result of improper grounding. Article 250 contains general requirements for grounding, bonding, and specific requirements for:

(a) Systems NOT requiring grounding

(b) Location of grounding connections

(c) Sizing and types

(d) Substitutions

(9) Article 250-28 covers main bonding jumpers.

(10) Article 250-50 covers the grounding electrode system. Table 250-66, sizing of grounding electrode conductor.

(11) Article 250-90 covers Bonding.

(12) Table 250-122, sizing of equipment grounding conductors.

f. Chapter 3 covers wiring methods and materials. This chapter concentrates more on the physical requirements of installing electrical equipment. This chapter also lists requirements of electrical materials, which includes characteristics of conductors, insulation and ampacities. Table 310-16 will be the most used table in this chapter. This table lists the ampacities of conductors.

(1) Article 300 covers wiring methods. Article 300-1 specifies that article 300 shall apply to all wiring installations unless modified by other articles. Article 300-5 covers underground installations.

(2) Article 305 covers temporary wiring. Article 305-1 applies to wiring that is classed below permanent wiring. Note however, that temporary wiring requirements are the same as permanent wiring except when modified by article 305.

(3) Article 310 covers conductors for general wiring. It covers general requirements for conductors, that include designators, insulation's, markings, mechanical strengths, ampacity ratings and uses. This article does not cover conductors that form an integral part of equipment, such as motors, motor controllers, and similar equipment, or to conductors specifically provided for, elsewhere in the Code.

(a) Table 310-13 covers conductor application and insulation's.

(b) Table 310-16 covers allowable ampacities of insulated conductors.

Articles 318 through 365 cover the many different methods of wiring. Each article lists the specific do’s and don’ts of that method. Included in the articles are information about sizes, uses, locations permissible, supports required, and construction specifications.

(4) Article 318 covers cable trays. It applies to cable tray assemblies, their mechanical construction, uses, supports, installations, and cable installation.

(5) Article 320 covers open wiring on insulators.

(6) Article 321 covers Messenger support wiring.

(7) Article 324 covers concealed knob and tube wiring.

(8) Article 325 covers integrated gas spacer cable (IGS).

(9) Article 328 covers flat conductor cable. (FCC)

(10) Article 330 covers mineral insulated, metal sheathed cable (MI).

(11) Article 331 covers electrical nonmetallic tubing.

(12) Article 333 covers armored cable (AC).

(13) Article 334 covers metal clad cable.

(14) Article 336 covers nonmetallic sheathed cable (NM, NMC, and NMS).

(15) Article 338 covers service entrance cable (SE and USE).

(16) Article 339 covers underground feeder and branch circuit cable (UF).

(17) Article 345 covers intermediate metallic conduit (IMC).

(18) Article 346 covers rigid metal conduit.

(19) Article 347 covers rigid nonmetallic conduit.

(20) Article 348 covers electrical metallic tubing (EMT).

(21) Article 349 covers flexible metallic tubing.

(22) Article 350 covers flexible metal conduit.

(23) Article 351 covers liquid tight flexible conduit.

(24) Article 352 covers surface raceways.

(25) Article 353 covers multi-outlet assembly.

(26) Article 354 covers under floor raceways.

(27) Article 356 covers cellular metal floor raceways.

(28) Article 358 covers cellular concrete floor raceways.

(29) Article 362 covers wire-ways.

(30) Article 363 covers flat cable assemblies (FC).

(31) Article 364 covers bus-ways.

(32) Article 365 covers cable bus.

(33) Article 370 applies to outlet, device, pull and junction boxes, conduit bodies, and fittings. Article 370 covers installation, use, and calculations.

(a) Table 370-16(a)

(b) Table 370-16(b)

(34) Article 373 covers cabinets, cutout boxes, and meter socket enclosures.

(35) Article 374 covers auxiliary gutters.

(36) Article 380 covers switches. Article 380 applies to all switches, switching devices, and circuit breakers where used as switches.

(37) Article 384 covers switchboards and panelboards. Article 384 applies to all switchboards and distribution boards installed for the control of light and power circuits. It also covers battery-charging panels supplied from light or power circuits.

g. Chapter 4 covers equipment for general use that is to say, equipment used everyday. Some of the equipment covered by this chapter are light fixtures, appliances, electric space heaters, generators, and transformer vaults. The pertinent articles for us cover appliances, electric heating, air conditioning and refrigeration.

(1) Article 400 covers flexible cords and cables.

(2) Article 402 covers fixture wires.

(3) Article 410 covers lighting fixtures, lampholders, lamps, and receptacles.

(a) Article 410-8 covers fixtures in clothes closets.

(b) Article 410-15 covers fixture supports.

(c) Article 410-100 covers track lighting.

(4) Article 411 covers lighting systems operating at 30 volts or less.

(5) Article 422 covers appliances.

(a) Article 422-13 covers storage-type water heaters (branch circuits).

(b) Article 422-18 covers support of ceiling-suspended (paddle) fans.

(6) Article 424 covers fixed electric space-heating equipment.

(7) Article 430 covers motors, motor circuits, and controllers. This article covers motors, branch circuit and feeder conductors and their protection, motor overload protection, motor control circuits, motor controllers, and motor control centers.

(a) Article 430-24 covers several motors, or a motor(s) and other load(s).

(b) Tables 430-147 through 430-152 covers ampacities of motors and protection devices.

(8) Article 440 covers air-conditioning and refrigerating equipment.

(9) Article 445 covers generators.

(10) Article 450 covers transformers and transformer vaults.

h. Chapter 5 contains information concerning special occupancies. Instead of running through each article, turn to the table of contents and find where chapter 5 is listed. If you read down the listing you will see the special occupancies covered. An example would be, if needing special information on gas stations read down the list and find article 514 - gasoline dispensing and service stations. Then turn to article 514 in the Codebook and look up the specific requirements.

i. Chapter 6 covers special equipment, such as welders, elevators, cranes, etc. If you work in base maintenance and there's a swimming pool under your care, article 680 will give you the rules and regulations because, as we all know, water and electricity do not mix.

j. Chapter 7 covers special conditions. You can find information on emergency systems, stand-by systems, fire protective signaling systems, and fiber optics.

k. Chapter 8 contains information on communications systems. This includes communication circuits, radio and TV, and community antenna television and radio (cable systems).

l. Chapter 9 contains examples and tables. Depending upon the computation performed, chapter 9 is used frequently. The example in chapter 9 will prove to clear up many things that often seem confusing at times.

m. When looking up information in the codebook, there are two sections that the book contains.

(1) The index is located in the back of the book. Many schools that teach the NEC feel the index will confuse those who use it. Each situation is referenced several times. That means if you look up an item you will be busy reading several articles. Some may find the index useful if the user can comprehend the way different words are used and their order for locating headings of needed situations. An example could be, looking for wire ampacity. You could look for wire ampacity, or look under ampacity, wire.

(2) The table of contents is located in the front of the book. This is your guide to using the NEC. In any situation, pick out the key electrical words. For example: what is the distance between supports for Romex? First you should know that Romex is a trade name for nonmetallic sheathed cable. Next go to the contents. You are talking about a wiring method and materials, therefore start in Chapter 3. Now read through chapter 3's listing and find nonmetallic sheathed cable. You find it at article 336. This has narrowed down your search to one article. Turn to article 336 in the Codebook and look at the bold print headings. At article 336-18 you find Supports and read the article.

CODE LOOK - UPS

1. Where shall the grounding electrode be placed for a separately derived A/C system that is required to be grounded?

2. Is a lighting fixture required above service equipment rated above 200 amperes?

3. Can a multi-wire branch circuit feed a split-wired receptacle circuit in a single family dwelling unit?

4. What is the maximum rating of an appliance that is cord and plug-connected and installed on a 30-amp branch circuit?

5. A total of 15-20 ampere receptacles are installed in a single family dwelling, which are in addition to the outlets required by

section 220-3(b). What load is given to those outlets for feeder sizing?

6. If a 20-ampere single pole circuit breaker is to be used as a switch to control 120 volt fluorescent lighting, how shall this breaker be marked (SWD)?

7. Can the structural metal frame of a building be used as the required equipment-grounding conductor for AC equipment?

8. Can a metal underground water pipe be used as a single grounding electrode for a single-family dwelling?

9. What is the size of the conductor, burial depth and length that is to be used as the grounding ring for the grounding electrode system?

10. What type of attachment plugs are required on portable lamps?

11. What article of the code requires non-current-carrying, metal parts of service equipment to be effectively bonded together

12. What article states that electrical equipment shall be in a neat and workmanlike manner?

13. What article states that disconnecting means, services, feeders, and branch circuits shall be legibly marked to indicate its purpose unless located and arranged so the purpose is evident?

14. Are standard receptacle outlets permitted for 125-volt, 20-ampere circuits used for electrical diagnostic equipment in a commercial garage?

15. A set of feeders for a sub-panel is routed through a service raceway, is there a violation?

16. What code section refers to lighting fixtures in clothes closets?

17. What code section tells the number of conductors allowed in different type boxes?

18. What section pertains to electric ranges in determining their load?

19. What code section requires all junction boxes to be covered?

20. What section requires all unused openings in boxes be closed?

6. <u>General Lighting Load</u>:

a. The general lighting loads are the first step in calculating the size of the service for a structure. The service and the system to be supplied is made up of the following:

(1) Service entrance conductors are connected to the service drop and are connected between the terminals of the service equipment. The service entrance conductors feed the structure being served. They will be required to handle the current flow to the service equipment and to the circuits throughout the structure. This is the reason sizing these conductors is important.

(2) Service equipment is the necessary equipment, usually consisting of a circuit breaker(s) or switch(es), fuse(s) and their accessories, connected to the load end of service entrance conductors to a building or other structure, or an otherwise designated area, and intended to constitute the main control and means of cutting off the supply of electricity. The service equipment uses these circuit breakers or fuses as over current protection devices to protect the circuits.

(3) Branch circuits are the circuit conductors between the final over current device protecting the circuit and the outlet(s).

b. The general lighting load is determined by the volt-amperes per square foot. It is then necessary to calculate the total square footage of the structure.

(1) Square footage is calculated by the formula length x width = sq. ft. In this example the structure is 50' long and 30' wide. This works out to be 50'x 30' = 1500 sqft. If the house has more than one floor, use the product of the length x width x the number of floors.

(2) Example of a two-story house works out as such:

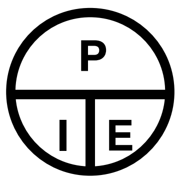
1st floor 30’ x 50’ = 1500 sqft
2nd floor 20’ x 50’ = 1000 sqft
1500 + 1000 = 2500 sqft

(3) The next step in calculating the general lighting load after obtaining the square footage of the structure is to apply the square footage to table 220-3(a) in the National Electrical code book. The use of table 220-3(a) is based on the type of occupancy that is found listed to the left of the table. Select a unit load per square foot in (VOLT-AMPERES) from the right side of the table. Multiply this unit load in volt-amperes per sqft by the square footage of the structure to be wired. Example: If you have a 1500 sqft structure that is a dwelling unit or house, look at the volt-amperes per sqft in table 220-3 (a) which corresponds with dwelling units. You find this to be 3 volt-amperes per sqft. By taking the total 1500 sqft of the structure and multiplying it by 3 volt-amperes per sqft you obtain a total of 4500 volt-amperes. This is the general lighting load for the dwelling.

Example 1. 1500 sqft x 3 volt-amperes = 4500 volt-amperes. (GENERAL LIGHTING LOAD)
Example 2. 2500 sqft x 3 volt-amperes = 7500 volt-amperes. (GENERAL LIGHTING LOAD)

7. **Calculating the Minimum Number of Branch Circuits Required.**

a. You now must find out how many circuits will be required for the general illumination or general lighting loads. In the first example you found that a dwelling of 1500 square feet, worked out to be 4500 volt-amperes. To find the number of branch circuits, perform ohms laws to convert volt-amperes to amperes. The NEC states that for the purpose of performing calculations, wattage and volt-amperes will be considered to be the same. The formula for power in watts states that voltage x amperage = wattage. Using this formula, if you know the wattage or in the case of the lighting load volt-amperes, you can divide the voltage into the volt-amperes or wattage to obtain amperes.



Example no.1 4500 volt-amperes divided by 120 volts = 37.5 amperes
Example no.2 7500 volt-amperes divided by 120 volts = 62.5 amperes

b. After obtaining the total amperage, determine how many circuits will be needed. Article 210-23 (a) states a 15 or 20 ampere branch circuit shall be permitted to supply lighting units, other utilization equipment or a combination of both. The rating of any one cord and plug-connected utilization equipment shall not exceed 80% of the branch circuit. The total rating of utilization equipment fastened in place shall not exceed 50 percent of the branch-circuit ampere rating where lighting units, cords-and plug-connected utilization equipment not fastened in place, or both, are also supplied. You need to find out if using 15 or 20 ampere circuits how many will fit into the 37.5-ampere requirement. This requires three 15A 2 wire or two 20A 2 wire circuits. In the second example it would work out to be five 15A 2 wire or four 20A 2 wire circuits. Article 210-11 covers branch circuits required. In no case shall the load on any circuit exceed the maximum specified by section 210-23.

8. **Calculate the Total Demand of the Structure.**

a. To calculate the total demand of a structure, there are several steps. Determining the general lighting load is the first. You must look at the loads and demands for the rest of the structure

(1) The small appliance load is the next step in the calculation of the total demand for the structure. Article 210-11(c)(1) states that in dwelling units two or more 20-ampere small appliance branch circuits shall be provided for all receptacle outlet(s) specified by section 210-52(b) for small appliance loads. Article 220-16(a) states in each dwelling unit the load shall be computed at 1500 volt-amperes for each two wire small appliance branch circuit required by section 210-11(c)(1) for small appliance by 15 - or - 20 ampere receptacles on 20 ampere circuits in the kitchen, pantry, dining room, and breakfast room.

(2) Article 210-52(c) further states that small appliance branch circuits shall be installed at counter spaces wider than 12 inches. You can take each small appliance circuit, the minimum required being two each at 1500 volt-amperes. This added together equal's 3000 volt-amperes. Add this demand to the general lighting load.

EXAMPLE:	GENERAL LIGHTING LOAD	4500 VOLT-AMPERE
	SMALL APPLIANCE CIRCUITS	3000 VOLT-AMPERES

(3) Article 210-52(f) states that in dwelling units at least one receptacle outlet shall be installed for the laundry. If a common laundry is provided in a multifamily building, or in other than a one-family dwelling where laundry facilities are not permitted, the laundry receptacle is not required. Article 210-11(c)(2) requires this to be a 20-ampere branch circuit with no other outlets. Article 220-16(b) states that a feeder load of not less than 1500 volt-amperes shall be included for each two wire laundry branch circuit installed. This being only one circuit, the minimum requirement would be a demand of 1500 volt-amperes. This is added to the other demands.

EXAMPLE:	GENERAL LIGHTING LOAD	4500 VOLT-AMPERES
	SMALL APPLIANCE CIRCUITS	3000 VOLT-AMPERES
	LAUNDRY	1500 VOLT-AMPERES

(4) At this point in the calculation it is subject to a demand factor, which is found in table 220-11, "lighting load demand factors".

(a) This table shows, based on the type of occupancy which is selected from the right hand side of the table, the demand that will apply. In the case of a dwelling unit the portion of lighting load and demand factor percent indicates that the first 3000 volt-amperes or less is taken at 100% demand and from 3001 to 120,000 at 35% demand and the remainder over 120,000 at 25% demand. If you apply the example, first add together all the volt-amperes that you have determined to be part of the calculation.

EXAMPLE:	GENERAL LIGHTING LOAD	4500 VOLT-AMPERES
	SMALL APPLIANCE	3000 VOLT-AMPERES
	LAUNDRY	+1500 VOLT-AMPERES
	TOTAL	9000 VOLT-AMPERES

TAKE THE FIRST 3000 AT 100% OF 9000 = ... 3000 VOLT-AMPERES
TAKE 3000 FROM 9000 = 6000 AT 35% = ...+2100 VOLT-AMPERES
NET GENERAL LIGHTING & SMALL APPLIANCE............. **5100 VOLT-AMPERES**

(NOTE--USE NET FOR REMAINING CALCULATIONS)

(5) Table 220-19 contains information on the demands for ranges. There are four notes that apply to table 220-19. Each note pertains to different situations with ranges.

(a) For ranges not rated over 12 kW use Table 220-19 column A.

EXAMPLE 1. One range rated at 10 kW = 8 kW demand factor
EXAMPLE 2. Five ranges rated at 9.5 kW = 20 kW demand factor

(b) NOTE 1. Over 12 kW through 27 kW ranges all of the same rating. For ranges individually rated more than 12 kW but not more than 27 kW, the maximum demand in column A shall be increased 5 percent for each additional kW of the rating or major fraction thereof by which the rating of individual ranges exceeds 12 kW

1 Following note 1. You see that this note applies "for ranges rated more than 12 kW but not more than 27 kW". Following the note, increase a 5% demand for each kW past 12 kW. If you take a range rated at 14 kW and increase 5% for each kW past 12 kW, you have:

EXAMPLE 1. One range rated at 14 kW
-12 kW
2 kW past 12 kW

2 Increase this 2 kW by 5% for each kW. Since there is 2 kW at 5% each, this = 10%. Note 1 states that you must apply this increase to the maximum demand in column "A" of table 220-19. Looking under one appliance at the right hand side of the table, in column “A” you find the maximum demand to be 8 kW. Since this is an increase of the maximum demand, 8000 at 10% = 800. 800 then is the amount of increase to the maximum demand.

8000.... MAX DEMAND COLUMN "A" FROM TABLE 220-19
x.10 ....TEN PERCENT WHICH CAME FROM THE 5% FOR EACH kW PASS 12 kW
800 ....THE AMOUNT OF INCREASE TO THE DEMAND OF COLUMN "A"
+8000 ....MAX DEMAND COLUMN "A", MUST BE ADDED TO THE INCREASE
8800 .... THE TOTAL DEMAND FOR THE 14 kW RANGE.

EXAMPLE 2. Two ranges rated at 17 kW
-12 kW
5 kW past 12 kW

3 Increase this 5 kW by 5% for each kW. Since there is 5 kW at 5% each, this = 25%. Note 1 states that you must apply this increase to the maximum demand for two ranges in column "A" of table 220-19. Looking under two appliances at the right hand side

of the table, in column “A” you find the maximum demand to be 11 kW. Since this is an increase of the maximum demand, 11000 at 25% = 2750. 2750 then is the amount of increase to the maximum demand.

```
 11000 ..MAX DEMAND COLUMN "A" FROM TABLE 220-19
 x .25 ..TEN PERCENT WHICH CAME FROM THE 5% FOR EACH kW PASS 12 kW
  2750...THE AMOUNT OF INCREASE TO THE DEMAND OF COLUMN "A"
+11000...MAX DEMAND COLUMN "A", MUST BE ADDED TO THE INCREASE
 13750...THE TOTAL DEMAND FOR THE 14 kW RANGE.
```

(c) Note 2 applies to ranges 8 3/4 kW through 27 kW ranges of unequal ratings. For ranges individually rated more than 8 3/4 kW and different rating, but none exceeding 27 kW, an average value of rating shall be computed by adding together the ratings of all ranges to obtain the total connected load (using 12 kW for any range rated less than 12 kW) and dividing by the total number of ranges; and the maximum demand in column a shall be increased 5 percent for each kW or major fraction thereof by which this average value exceeds 12 kW.

EXAMPLE 1. Taking two ranges, one 14 kW the other 20 kW, compute the average value rating by adding together the kW ratings of all the ranges.

```
  14 kW RANGE
 +20 kW RANGE
  34 kW
```

DIVIDE BY THE NUMBER OF RANGES INTO THE SUM OF THE kW RATING OF THE RANGES

34 kW DIVIDED BY 2 = 17 kW IS THE AVERAGE kW
TO FIND EACH kW OVER 12 kW, TAKE THE AVERAGE AND SUBTRACT 12 kW

```
 17 kW
-12 kW
  5 kW
```

AN INCREASE OF 5% FOR EACH kW OVER 12 kW. IN THIS EXAMPLE WE FIND 5% X 5 kW = 25% INCREASE TO COLUMN "A". COLUMN "A" SHOWS 11 kW FOR TWO APPLIANCES.

```
  11000 - FOUND IN COLUMN "A" FOR TWO APPLIANCES.
    x.25 - 25% INCREASE.
    2.75 kW
 +11000 - ADDED BACK TO THE INCREASE
  13.75 kW - TOTAL DEMAND FOR BOTH RANGES.
```

EXAMPLE 2. Taking three ranges, one 13 kW, one 15 kW, and the other 18 kW, compute the average value rating by adding together the kW ratings of all the ranges.

```
  13 kW RANGE
  15 kW RANGE
```

```
 +18 kW RANGE
  46 kW
```

DIVIDE BY THE NUMBER OF RANGES INTO THE SUM OF THE kW RATING OF THE RANGES

46 kW DIVIDED BY 3 = 15.3 kW IS THE AVERAGE kW
TO FIND EACH kW OVER 12 kW, TAKE THE AVERAGE AND SUBTRACT 12 kW

```
 15 kW
-12 kW
  3 kW
```

AN INCREASE OF 5% FOR EACH kW OVER 12 kW. IN THIS EXAMPLE WE FIND 5% X 3 kW = 15% INCREASE TO COLUMN "A". COLUMN "A" SHOWS 14 kW FOR THREE APPLIANCES.

```
  14000 - FOUND IN COLUMN "A" FOR THREE APPLIANCES.
   x.15 - 15% INCREASE.
    3.5 kW
 +14000 - ADDED BACK TO THE INCREASE
   17.5 kW - TOTAL DEMAND FOR ALL THREE RANGES.
```

(d) NOTE 3 covers ranges over 1 3/4 kW through 8 3/4 kW. In lieu of the method provided in column "A", it shall be permissible to add the nameplate ratings of all ranges rated more than 1 3/4 kW but not more than 8 3/4 kW and multiply the sum by the demand factors specified in column "B" or "C" for given number of appliances.

EXAMPLE 1. FIVE RANGES ALL RATED AT 4 kW, SEVEN RANGES ALL RATED AT 5 kW, AND THREE RANGES ALL RATED AT 6 kW. THEY ALL FALL UNDER COLUMN “C”.

```
5 RANGES X 4 kW =     20 kW
7 RANGES X 5 kW =     35 kW
3 RANGES X 6 kW =    +18 kW
                      73 kW........SUM OF ALL THE NAME PLATE RATINGS
```

THE NOTE FURTHER STATES, MULTIPLY THE SUM BY THE DEMAND FACTORS SPECIFIED IN COLUMN "B" OR "C" FOR THE GIVEN NUMBER OF APPLIANCES.

32% IS FOUND IN COLUMN "C" FOR 15 RANGES

```
THE SUM OF ALL THE NAME PLATE RATINGS ......... 73 kW
THE 32% FOUND IN COLUMN "C" FOR 15 RANGES ..... x.32
THE TOTAL DEMAND FOR ALL 15 RANGES ............ 23.36 kW
```

EXAMPLE 2. ONE RANGE RATED AT 2 kW, TWO RANGES EACH RATED AT 7 kW,
COLUMN “B” - 1 RANGE 2 kW. 80% IS FOUND IN COLUMN “B” FOR 1 RANGE
.80 x 2000 = 1600
COLUMN “C” - 2 RANGES 7 kW. 65% IS FOUND IN COLUMN “C” FOR TWO RANGES
.65 x 14000 = 9100
ADD THE RESULTS OF COLUMNS “B” AND “C” TO FIND TOTAL DEMAND
1600 + 9100 = 10700

10.7 kW = TOTAL DEMAND FOR ALL THREE RANGES

(e) Note 4 provides, the branch circuit load for one range in accordance with table 220-19. The branch circuit load for one wall-mounted oven or one counter-mounted cooking unit shall be the nameplate rating of the appliance. The branch circuit load for counter top cooking unit and not more than two wall mounted ovens, all supplied from a single branch circuit and located in the same room shall be computed by adding the name plate rating of the individual appliances and treating this total as equivalent to one range.

EXAMPLE 1. ONE RANGE RATED AT 12 kW

USE DEMAND FACTOR IN COLUMN “A” FOR ONE RANGE

8 kW = BRANCH CIRCUIT LOAD

EXAMPLE 2. ONE 6 kW COOK TOP, TWO 6 kW WALL MOUNTED OVENS.

THE NOTE STATES THE BRANCH CIRCUIT LOAD SHALL BE COMPUTED BY ADDING THE NAMEPLATE RATINGS OF THE INDIVIDUAL APPLIANCES AND TREATING THIS TOTAL AS EQUIVALENT TO ONE RANGE

6 kW COOK TOP
6 kW WALL MOUNTED OVEN
+6 kW WALL MOUNTED OVEN
18 kW THE SUM OF THE INDIVIDUAL APPLIANCES

TREATING THIS AS THE EQUIVALENT TO ONE RANGE THE MAXIMUM DEMAND IN COLUMN "A" SHALL BE INCREASED 5% FOR EACH ADDITIONAL kW OF RATING OR MAJOR FRACTION THEREOF WHICH THE RATING OF INDIVIDUAL RANGES EXCEEDS 12 kW

18 kW
+12 kW
6 kW

5% FOR EACH kW, THIS BEING 6 kW WORKS OUT TO BE 30%
5% x 6 = 30% INCREASE TO COLUMN "A" WHICH IS 8000

8000 DEMAND FROM COLUMN “A” FOR ONE RANGE
x .30
2400 30% INCREASE
+8000 ADDED BACK TO THE INCREASE
10400 TOTAL DEMAND FOR THE BRANCH CIRCUIT LOAD

(6) Article 220-18 covers electric clothes dryers - dwelling unit(s). This article states, the load for household electric clothes dryers in a dwelling unit(s) shall be 5000 watts (volt-amperes) or the name plate rating, whichever is larger, for each dryer served. The use of the demand factor in table 220-18 shall be permitted.

EXAMPLE 1. ONE DRYER RATED AT 4500 WATTS

IF YOU HAVE A DRYER WITH THE NAMEPLATE VALUE OF 4500 WATTS, THE NOTE STATES YOU MUST TAKE THIS AT 5000 WATTS.

5000 WATTS = DEMAND TOTAL FOR DRYER IN EXAMPLE 1

EXAMPLE 2. ONE DRYER RATED AT 5500 WATTS

IF YOU HAVE A DRYER WITH THE NAMEPLATE VALUE OF 5500 WATTS. THE NOTE STATES TO TAKE THE DRYER AT THE NAMEPLATE RATING IF IT IS GREATER THAN 5000 WATTS. THEN IT WOULD BE TAKEN AT 5500 WATTS

EXAMPLE 3. 5 DRYERS ALL WITH A NAMEPLATE VALUE OF 5000 WATTS.

GET THE TOTAL DEMAND BY ADDING THE TOTAL NUMBER OF WATTS AND APPLY THE DEMAND FACTOR FOR THE NUMBER OF DRYERS FOUND IN TABLE 220-18.

5 DRYERS x 5000 WATTS = 25000 WATTS TOTAL

25000 TAKEN AT 80% WHICH IS FOUND IN TABLE 220-18 UNDER 5 DRYERS

25000	TOTAL WATTS OF ALL FIVE RANGES
x .80	80% DEMAND FROM TABLE 220-18 UNDER 5 DRYERS
20,000	TOTAL DEMAND FOR ALL FIVE RANGES

(7) Article 220-17 covers appliance load for dwelling units. It states that it shall be permissible to apply a demand factor of 75 percent to the nameplate ratings of FOUR or more appliances fastened in place, other than electric ranges, clothes dryers, space heating equipment, or air conditioning equipment, that are served by the same feeder or service.

(a) Examples of appliances fastened in place are water heaters, garbage disposals, trash compactors, dishwashers, attic fans ECT...

(b) This demand is commonly referred to as the “fixed appliance” load.

EXAMPLE 1. A DISHWASHER RATED AT 1200VA, A WATER HEATER RATED AT 4500VA, AND A GARBAGE DISPOSAL RATED AT 1500VA.

THE NOTE STATES TO APPLY THE DEMAND FACTOR OF 75% FOR FOUR OR MORE APPLIANCES FASTNED IN PLACE.

DISHWASHER	1200VA	
WATER HEATER	4500VA	
GARBAGE DISPOSAL	+1500VA	
	7200VA	TOTAL FIXED APPLIANCE LOAD

EXAMPLE 2. A DISHWASHER RATED AT 1200VA, A WATER HEATER RATED AT 4500VA, A ATTIC FAN RATED AT 700VA, AND A GARBAGE DISPOSAL RATED AT 1500VA.

DISHWASHER	1200VA	7900VA
WATER HEATER	4500VA	X.75
ATTIC FAN	700VA	5925VA
GARBAGE DISPOSAL	+1500VA	
	7900VA	

5925VA IS TOTAL DEMAND FOR FIXED APPLIANCES

(8) Article 220-14 covers motors. It refers you to section 430-24, which covers several motors or a motor(s) and other loads. It states that conductors supplying several motors, or a motor(s) and other load(s), shall have an ampacity at least equal to the sum of the full-load current rating as determined by section 430-6(a)(1) of all the motors, plus 25 percent of the highest rated motor in the group, plus the ampere rating of other loads.

(a) This is commonly referred to as the “largest motor” load.

(b) The largest motor load will generally come from the fixed appliances.

EXAMPLE 1. A DISHWASHER RATED AT 1200VA, A WATER HEATER RATED AT 4500VA, AN ATTIC FAN RATED AT 700VA, AND A GARBAGE DISPOSAL RATED AT 1500VA. THE LARGEST POWER CONSUMER IS THE WATER HEATER, HOWEVER THE WATER HEATER CANNOT BE CONSIDERED BECAUSE IT CONTAINS NO MOTOR. THE NEXT LARGEST IS THE DISHWASHER, BUT THE DISHWASHER CONTAINS ONLY A SMALL MOTOR. THE MAIN POWER CONSUMER IN THE DISHWASHER IS A HEATING ELEMENT. NEXT IS THE GARBAGE DISPOSAL. IT IS THE CORRECT CHOICE BECAUSE ALL 1500VA ARE CONSUMED BY A MOTOR.

1500VA
x.25
375VA IS THE TOTAL LARGEST MOTOR LOAD

(9) Article 220-21 covers noncoincident loads. It states, where it is unlikely that two or more noncoincident loads will be in use simultaneously, it shall be permissible to use only the largest load(s) that will be used at one time, in computing the total load of a feeder or service. This normally pertains to heating and air conditioning loads since only one will operate at a time.

EXAMPLE 1. HEATING LOAD OF 10KVA AND AN AIR CONDITIONING LOAD OF 7.5KVA. THE HEATING LOAD OF 10KVA WILL BE USED SINCE IT IS THE LARGEST.

10KVA HEAT AND A/C LOAD

(10) Compute the total demand. At this point we have to take all of the previous calculations and add them together to find the total demand.

EXAMPLE: THE DWELLING HAS A FLOOR AREA OF 1500 SQ. FT. APPLIANCES ARE A 12 kW RANGE AND A 5.5 kW DRYER. APPLIANCES FASTENED IN PLACE

INCLUDE A 4500VA WATER HEATER, A 1200VA DISHWASHER, 700VA ATTIC FAN, AND A 1500VA GARBAGE DISPOSAL. THERE IS 10KW OF HEAT AND 7.5 kW OF A/C.

GENERAL LIGHTING .... 4500 VOLT-AMPERES
SMALL APPLIANCE LOAD .... 3000 VOLT-AMPERES
LAUNDRY ....+1500 VOLT-AMPERES
TOTAL GENERAL LIGHT & SMALL APPLIANCE ...... 9000 VOLT-AMPERES

3000 VOLT-AMPERES AT 100% .... 3000 VOLT-AMPERES
9000 - 3000 = 6000 VOLT-AMPERES AT 35% ....+2100 VOLT-AMPERES
NET ..... 5100 VOLT-AMPERES

NET .... 5100 VOLT-AMPERES
RANGE LOAD .... 8000 VOLT-AMPERES
DRYER LOAD .... 5500 VOLT-AMPERES
FIXED APPLIANCE .... 5925 VOLT-AMPERES
HEATING AND A/C ....10000 VOLT-AMPERES
LARGETS MOTOR ....+ 375 VOLT-AMPERES
TOTAL LOAD ....34,900 VOLT-AMPERES

9. Calculating the Minimum Service Entrance Conductor:

a. In order to calculate the service you must first find the amperage of the total connected load. To do this you must use the formula for power in watts. Divide the total connected load by the voltage that serves the structure. Dwelling units will normally be 240volts, however always check to make sure what the applied voltage is. The size of the service must be large enough for the total amperage.

EXAMPLE: POWER FORMULA STATES E x I = P

E = VOLTAGE, I = CURRENT, AND P = POWER OR WATTAGE.

TAKE THE TOTAL WATTAGE OF THE STRUCTURE, 34,900 AND DIVIDE IT BY THE VOLTAGE, 240. THE RESULT IS 145.41 AMPERES.

b. The service entrance conductor feeds the electrical service equipment and must be large enough to handle the total load and sized to the service equipment. Article 230-79(c) covers the minimum size required for a dwelling service. The codebook gives two options for sizing the service and the service entrance conductors.

(1) Article 310-15(b)(6) covers sizing single-phase dwelling services. For our example the minimum size service would be 150amps with ungrounded conductors of 2/0 aluminum or 1AWG copper.

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(2) Article 240-6 covers standard ampere ratings for overcurrent devices. The minimum size for our example is 150 amps. Next we have to go to table 310-16 for conductor sizing. Article 110-14(c) tells us to use the 75-degree column on table 310-16. The minimum size ungrounded conductor would be 3/0 aluminum or 1/0 copper.

10. <u>Calculating the Neutral Conductor</u>:

a. The grounded conductor is used for the return path of the unused portion of current. It is important that the neutral conductor be able to handle the amount of current flow back to the source. In order to calculate the minimum size of the neutral conductor, you must know the total demand of amperage for the structure being served. In the ongoing example you learned that the structure has a total demand of 145.41 amperes. You sized the service entrance conductors for 150 amperes. Article 220-22 covers the requirements in calculating the steps for the neutral conductor. This article states the maximum unbalanced load shall be the maximum net computed load between the neutral and any one ungrounded conductor. It also states that a feeder supplying household electric ranges, wall-mounted ovens, counter-mounted cooking units, and electric dryers the maximum unbalanced load shall be considered as 70 percent of the load on the ungrounded conductors as determined in accordance with the applicable tables for these items. This means that the calculation will be the same as the service with the exception of the range and the dryer. Also the appliances fastened in place may be different because some 240volt appliances do not require a neutral such as a water heater and will not be a part of the neutral calculation.

EXAMPLE

NET	5100 VOLT-AMPERES
RANGE LOAD @ 70%................................	5600 VOLT-AMPERES
DRYER LOAD @ 70%................................	3850 VOLT-AMPERES
FIXED APPLIANCE	3400 VOLT-AMPERES
HEATING AND A/C	10000 VOLT-AMPERES
LARGETS MOTOR	+ 375 VOLT-AMPERES
TOTAL NEUTRAL LOAD	**28,325 VOLT-AMPERES**

b. The next step is to find the neutral amperage using the formula for power in watts.

EXAMPLE: POWER FORMULA STATES E x I = P

E = VOLTAGE, I = CURRENT, AND P = POWER OR WATTAGE.

TAKE THE TOTAL WATTAGE OF THE NEUTRAL, 28,325 AND DIVIDE IT BY THE VOLTAGE, 240. THE RESULT IS 118.02 AMPERES

c. Using the 75-degree column of table 310-16 size the neutral conductor. The minimum size grounded conductor would be 1/0 aluminum or 1AWG copper.

d. Prior to the 1996 edition of the codebook it was a common to size the neutral conductor two sizes smaller than the largest current carrying conductor. And is sometimes still done today.

e. If the neutral is the same size as the largest service entrance conductor, there is no question of its ability to handle the unused portion of current.

11. <u>Calculating the Overcurrent Protection Devices Required</u>:

a. Selecting an over-current device to protect your circuit is one of the most important steps in designing an electrical circuit. The thing to remember is to **ensure** that the over-current device amperage rating does not exceed the current carrying capacity of the circuit conductors. Example: A circuit constructed of 8AWG THWN copper conductors must have an over-current device of 50amps or less.

b. There are two places over-current protection will be placed in an interior wiring system.

(1) At the service. The main breaker must be sized to the total demand and the service entrance conductors will be sized according to the size of the main.

(2) Each branch circuit will also require over-current protection. You will need to research the codebook because there are different requirements for different types of branch circuits.

c. Article 240-6 covers standard sizes of fuses and circuit breakers.

12. <u>Calculating Grounding & Bonding Electrode Conductors</u>:

a. The grounding electrode conductor provides a path from the panel to the grounding electrode system. Bonding jumpers ensure electrical continuity of all metallic components of a system. In order to size the grounding and bonding electrode conductors, you must first go through the steps for calculating a total demand for the structure. The grounding electrode conductor is based on the size of the largest service entrance conductor. Article 250-66 covers all the exceptions in dealing with the size of grounding electrode conductor.
Table 250-66 is broken down as follows.

(1) Across the top to the left of table 250-66 the heading reads, "size of the largest service-entrance conductor". Below this heading are two columns.

(a) The first column is a list for conductor sizes made of copper.

(b) The second column is a list for conductor sizes made of aluminum or copper-clad aluminum.

(2) Across the top to the right of table 250-94 the heading reads, "size of electrode conductor". Below this heading are two columns.

(a) The first column is a list for grounding conductors made of copper.

(b) The second column is a list for grounding conductors made of aluminum or copper-clad aluminum.

EXAMPLE: OUR LARGEST SERVICE ENTRANCE CONDUCTOR IS 3/0. IF WE SELECTED A COPPER GROUNDING ELECTRODE CONDUCTOR IT WOULD BE 6AWG.

b. Bonding jumpers on the supply side of the service shall be sized according to table 250-66.

c. Bonding jumpers on the load side of the service shall be sized according to table 250-122.

d. Equipment grounding conductors shall be sized according to table 250-122.

13. <u>Sizing Branch Circuit Conductors</u>:

a. During the lesson, I have covered the power in watts formula and demand factors. These are important in determining the proper size conductors needed. Perform the following steps to size branch circuits:

(1) Calculate the total amperes for the branch circuit. Use ohms law to calculate this.

(2) To calculate and select an over current protection device for branch circuits, you must first apply demand factors where needed. Use the National Electric Code for the proper demand factors. Article 220-3 (b) covers the minimum load for each outlet for general use. This article states that outlets for general use under "other outlets" for receptacle outlet, each single or each multiple receptacle on one strap shall be considered at not less than 180 volt-amperes. It is further important to understand that the breaker or fuse determines the size of the circuit, i.e. a circuit protected by a 20-ampere breaker is a 20-ampere circuit.

(3) Article 240-6 lists the standard ampere rating for fuses and inverse time circuit breakers. In order to select an over current protection device for the circuit, you must go through the steps for calculating the total demand for the circuit. Perform ohms law to convert the total volt-amperes to amperes. Using the selection of standard ampere rating for fuses and inverse time circuit breakers, select a breaker equal to or less than the total amperage of the circuit.

(4) Determine the application in which the conductors will be used. In determining the application, you must know information such as, will the circuit be in a dry or damp location, or will it be used in a special application. Article 310-13 covers information on application of conductors. This will allow you to select the type of wire or trade name and the insulation or covering of the conductors.

(5) After you have determined the type of wire and the size of the over-current device, you must select the proper size conductors. I have covered table 310-16 and its use in previous discussions. Table 310-16 may be used to size the conductors for branch circuits by applying the type of wire with the amperage rating. Symbols may be found along side the amperage rating which will refer you to footnotes. These footnotes may give the amperage allowed.

14. <u>Sizing Boxes</u>:

a. Article 370-16 covers the number of conductors in outlets, devices, junction boxes, and conduit bodies. This article states; boxes shall be of sufficient size to provide free space for all conductors enclosed in the box. There are two tables used for sizing boxes and conduit bodies.

(1) The maximum number of conductors permitted in standard boxes that are not marked with cubic inch capacity are listed in table 370-16 (a). This table can be used by itself providing that all the conductors present in the box are the same size.

(2) For combinations of conductor sizes shown in table 370-16(a), the maximum number of conductors permitted shall be computed using the volume per conductor listed in table 370-16 (b).

(3) Before you use either table you must understand how to do box fill calculations. Paragraphs (1) through (5) explain how.

(a) **Conductor Fill**. Each conductor that originates outside the box and terminates or is spliced within the box shall be counted once, and each conductor that passes through the box without splice or termination shall be counted once. The conductor fill, in cubic inches, shall be computed using Table 370-16(b). A conductor, no part of which leaves the box, shall not be counted.

(b) **Clamp Fill**. Where one or more internal cable clamps, whether factory or field supplied, are present in the box, a single volume allowance in accordance with Table 370-16(b) shall be made based on the largest conductor present in the box. No allowance shall be required for a cable connector with its clamping mechanism outside the box.

(c) **Support Fittings Fill**. Where one or more fixture studs or hickeys are present in the box, a single volume allowance in accordance with Table 370-16(b) shall be made for each type of fitting based on the largest conductor present in the box.

(d) **Device or Equipment Fill**. For each yoke or strap containing one or more devices or equipment, a double volume allowance in accordance with Table 370-16(b) shall be made for each yoke or strap based on the largest conductor connected to a device(s) or equipment supported by that yoke or strap.

Equipment Grounding Conductor Fill. Where one or more equipment grounding conductors or equipment bonding jumpers enters a box, a single volume allowance in accordance with Table 370-16(b) shall be made based on the largest equipment grounding conductor or equipment bonding jumper present in the box. Where an additional set of equipment grounding conductors, as permitted by Section 250-146(d), is present in the box, an additional volume allowance shall be made based on the largest equipment grounding conductor in the additional set.

EXAMPLE: FIND A SUFFICIENT SIZE JUNCTION BOX TO RECEIVE THE FOLLOWING CONDUCTORS BY APPLYING ARTICLE 370-16.

1-CABLE OF 6/2, 1-CABLE OF 10/2, 1-CABLE OF 12/2

EACH CONDUCTOR WILL RECEIVE A VALUE IN CUBIC INCHES ACCORDING TO WIRE SIZE FROM TABLE 370-16(B). IN THE EXAMPLE YOU WILL WORK THIS OUT BY TAKING THE CUBIC INCHES X NUMBER OF CONDUCTORS. NOTE: THE FIRST NUMBER OF THE CABLE IS THE SIZE OF THE CONDUCTORS IN AWG AND THE SECOND REPRESENTS THE NUMBER OF CONDUCTORS. HOWEVER DON'T FORGET THE SECOND NUMBER DOES NOT INCLUDE THE GROUND.

IN THE EXAMPLE THE WIRE MUST RECEIVE A TOTAL IN CUBIC INCHES

NO. 6 = 5.00 CUBIC PER CONDUCTOR
NO. 10 = 2.50 CUBIC PER CONDUCTOR
NO. 12 = 2.25 CUBIC PER CONDUCTOR

5.00 x 3 =	15.00	(1 extra for all grounds)
2.50 x 2 =	5.00	
2.25 x 2 =	+4.50	
	24.50	= TOTAL CUBIC INCHES

TABLE 370-16(a) CONTAINS A COLUMN OF MINIMUM CUBIC INCHES. FINDING THE CUBIC INCHES WHICH ARE EQUAL TO OR GREATER THAN THOSE IN THE EXAMPLE, YOU FIND 24.5. TO THE RIGHT OF THESE, THE MINIMUM SIZE BOX IS FOUND TO BE A 4 11/16 X 1 1/4 SQUARE.

15. CONDUIT:

a. Conduit is a type of tubing that is used to enclose and protect electrical wiring. Conduit in most cases is made mechanically strong, fireproof, moisture or liquid tight with smooth interiors to prevent damage to conductors. Conduit that is made of metal has the ability to be grounded continuously. It comes in standard 10-foot lengths with sizes ranging from 1/2" to 6" in diameter. It is important that the conduit be sized properly for the number of conductors. Chapter 9 tables and examples cover the different methods of sizing the conduit. New types of conduit are developed constantly. Most but not all types of conduit are listed in the codebook. In a case where a type of conduit is not listed make sure to follow the manufacturers instructions.

b. There are several tables that deal with sizing conduit and there are nine notes that deal with the tables. By referencing the notes you can find out what table is needed for your particular situation.

(1) See Appendix C for the maximum number of conductors and fixture wires, **all of the same size** (total cross-sectional area including insulation) permitted in trade sizes of the applicable conduit or tubing.

(2) Table 1 applies only to complete conduit or tubing systems and is not intended to apply to sections of conduit or tubing used to protect exposed wiring from physical damage.

(3) Equipment grounding or bonding conductors, where installed, shall be included when calculating conduit or tubing fill. The actual dimensions of the equipment grounding or bonding conductor (insulated or bare) shall be used in the calculation.

(4) Where conduit or tubing nipples having a maximum length not to exceed 24 in. (610 mm) are installed between boxes, cabinets, and similar enclosures, the nipples shall be permitted to be filled to 60 percent of their total cross-sectional area, and Section 310-15(b)(2)(a) adjustment factors need not apply to this condition.

(5) For conductors not included in Chapter 9, such as multi-conductor cables, the actual dimensions shall be used.

(6) For combinations of conductors of different sizes, use Tables 5 and 5A for dimensions of conductors and Table 4 for the applicable conduit or tubing dimensions.

(7) When calculating the maximum number of conductors permitted in a conduit or tubing, all of the same size (total cross-sectional area including insulation), the next higher whole number shall be used to determine the maximum number of conductors permitted when the calculation results in a decimal of 0.8 or larger.

(8) Where bare conductors are permitted by other sections of this Code, the dimensions for bare conductors in Table 8 shall be permitted.

(9) A multi-conductor cable of two or more conductors shall be treated as a single conductor for calculating percentage conduit fill area. For cables that have elliptical cross sections, the cross-sectional area calculation shall be based on using the major diameter of the ellipse as a circle diameter.

16. Branch Circuit Schedule:

a. A branch circuit schedule is a form or chart. When filled out it will show at a glance; the receptacles, switch outlets, and lighting outlets on each circuit. This is very helpful when you start identifying material items required. In order to prepare a branch circuit schedule you must first prepare a diagram using a floor plan showing all circuits.

(1) This plan shows each separate circuit and approximate location of each conductor or cable. This plan also shows the location of all the electrical outlets, switches and lighting fixtures.

(2) In drawing out the circuits on a floor plan you must first research the device or item which is being installed. The National Electric Code covers many rules that are intended to ensure that the electrical system best serves the user.

(a) Switches should be placed where they are accessible without reaching behind doors. With the wide selection of switches on the market, no one should have to walk into a dark room to turn on a light. Article 210-70 states in dwelling unit(s), at least one wall switch-controlled lighting outlet shall be installed in every habitable room: in bathrooms, hallways, stairways, attached garages, and detached garages with electric power; and at outdoor entrances or exits. At least one lighting outlet controlled by a light switch located at the point of entry to attic, under floor spaces, utility room and basement shall be installed only where these spaces are used for storage or contain equipment requiring servicing. When installing a wall switch for lighting on stairways, there shall be a wall switch at each floor level where the difference between floor levels is six steps or more.

(b) The required placement of receptacle outlets can be found in several articles in the Codebook. The following articles cover some of these requirements.

<u>1</u> Information about receptacle outlets in dwellings is covered in article 210.52. This article states in every kitchen, family room, dining room, living room, parlor, library, den, sun room, bedroom, recreation room, or similar room or area of dwelling units, receptacle outlets shall be installed so that no point along the floor line in any wall space is more than 6 feet measured horizontally.

<u>2</u> Article 210-52(b) states: in the kitchen, pantry, breakfast room, dining room, or similar area of a dwelling unit, the two or more 20-ampere small-appliance branch circuits required by Section 210-11(c)(1) shall serve all receptacle outlets covered by Sections 210-52(a) and (c) and receptacle outlets for refrigeration equipment. Article 210-52(b)(2) requires the two or more small-appliance branch circuits specified in (b)(1) shall have no other outlets. Article 210-52(b)(3) states: receptacles installed in a kitchen to serve countertop surfaces shall be supplied by not less than two small-appliance branch circuits, either or both of which shall also be permitted to supply receptacle outlets in the same kitchen and in other rooms specified in Section 210-52(b)(1). Additional small-appliance branch circuits shall be permitted to supply receptacle outlets in the kitchen and other rooms specified in

Section 210-52(b)(1). No small-appliance branch circuit shall serve more than one kitchen. Article 210-52(c) further covers receptacle outlets for counter tops.

3 Article 210-52(d) requires that at least one wall receptacle outlet shall be installed in bathrooms within 36 in. (914 mm) of the outside edge of each basin. The receptacle outlet shall be located on a wall that is adjacent to the basin location. Article 210-8(a)(1) further requires this outlet to be ground-fault protected.

4 Article 210-52(e) states: for a one-family dwelling and each unit of a two-family dwelling that is at grade level, at least one receptacle outlet accessible at grade level and not more than 6½ ft (1.98 m) above grade shall be installed at the front and back of the dwelling. Article 210-8(a)(3) requires this outlet to also be ground-fault protected.

5 Article 210-52(f) requires in dwelling units at least one receptacle outlet shall be installed for the laundry.

6 Article 210-52(g) states: for a one-family dwelling, at least one receptacle outlet, in addition to any provided for laundry equipment, shall be installed in each basement and in each attached garage, and in each detached garage with electric power. See Sections 210-8(a)(2) and (a)(5). Where a portion of the basement is finished into a habitable room(s), the receptacle outlet required by this section shall be installed in the unfinished portion.

7 Article 210-52(h) requires hallways of 10 feet or more in length to have at least one receptacle outlet.

(3) After looking up the requirements for the circuits to be installed, the following steps should be followed for completing the wiring diagram:

(a) Draw the symbols for all the required component outlets and devices in place on the floor plans where they meet Code standards and best serve the user of the electrical system.

(b) Calculate the amperes for each component and select the number of fixtures and devices to be included in each branch circuit so that the total amperes of that circuit meets the requirement of the code and does not exceed the planed capacity or size of the selected conductor to supply that branch circuit. You must research demands for loads to be served by the system. For example: the demand for general outlets is 180 volt-amperes, laundry circuit is 1500 volt-amperes, and the small appliance circuits are to be rated 1500 each, etc.

(c) Draw lines indicating the route the cables will travel, and draw lines crossing the cable to indicate the number of wires required for the circuit to function.

(d) Draw the symbol for each circuit, and place the number along side this symbol to identify the circuit. There should only be one circuit using any one number for identification.

(4) Starting off with the first circuit number, start filling out the branch circuit schedule.

(a) Write the number of the first circuit in the far-left column. The circuit numbers need to be in numerical order.

(b) In the second column write the location for each area the circuit travels. This is for any component that is part of that circuit which travels into any room.

(c) Listed across the top of the branch circuit schedule are the headings for columns such as lighting outlets, switch outlets and receptacle outlets. Under each of these headings are columns labeled by the type of lighting outlet or type of switch etc. In these columns corresponding to the circuit number to the left, is the quantity of those components.

17. <u>Branch Circuit Material Schedule</u>:

a. When prepared, the branch circuit schedule contains the required amount of material to wire the building. This form will take more time than the others to complete.

b. The first column lists the circuit numbers for each circuit. Across the top are headings, below that are spaces for the quantity of those items that correspond with the circuit in which they are intended to be a part. All columns have a total.

c. The section for cable has three columns. Headings for each column identify the wire size and number of conductors of the cable, i.e. 12-3 or 12-2. These columns can also be used for conduit by writing in the size of conduit in the heading. Below the heading list the amount of material in feet according to the amount required for each circuit. Enter the subtotal for the amount of material below. Increase the subtotal for wire or conduit by 10% to ensure enough materials. The best method to estimate the amount of cable required for each circuit is to use a scale and measure the distance on the plan. The route in which the wire will travel is important i.e. will it travel through the attic or under the floor.

d. The section for boxes has three columns. Each column is labeled with the type and size of box for the column. Enter in these columns the quantity of each type of box corresponding to the proper circuit.

e. The section for switches has two columns. Each column is labeled to identify the types of switches. Enter in each column the quantity of switches for each type, corresponding to the proper circuit.

f. The section for receptacles has four columns. Each column is labeled to identify the type of receptacle. Enter in each column the quantity of receptacles according to type that corresponds to the proper circuit.

g. The section for plates has four columns. Each column is labeled to identify the type of plate and/or cover. Enter in each column the quantity of plates and covers for each type that corresponds to boxes and the proper circuit.

h. The last three columns list wire nuts, hangers and box ground screws. Below each of these headings are the quantity of each item which corresponds with the proper circuit.

18. <u>Service Material Schedule</u>:

a. Enter the items needed for the service in the first column of this form. Some items like the service entrance wire, main breaker and grounding electrode conductor require a total calculation for the demand on the structure and the cross reference of tables for sizes.

b. List the number of the items needed in the second column.

c. Show the footage in the third column if it is applicable.

19. <u>Lighting Fixture Schedule</u>:

a. The lighting fixture schedule shows lighting fixtures on each circuit.

(1) There are several different types of lighting fixtures that are identified by letters.

(a) The letters that identify the type of lighting fixture are placed on the electrical diagram.

(b) The lighting fixture schedule list columns with these letters that identify the type of fixture. The number of lighting fixtures for each type is listed and corresponds to the circuit it is supplied by.

b. Always include a legend that designates which type of lighting fixtures are represented by each of the letters. For example: All single bulb 60WATT fixtures will be designated as type “A” fixtures.

<u>REFERENCES</u>: TM 5-704
Wiring Skills, Unit 1
FM 5-424
NATIONAL ELECTRICAL CODE